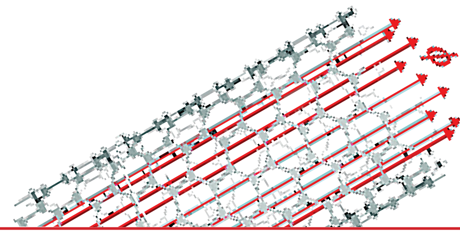
MPA materials matter

January 2008

Newsletter of the Materials Physics and Applications Division



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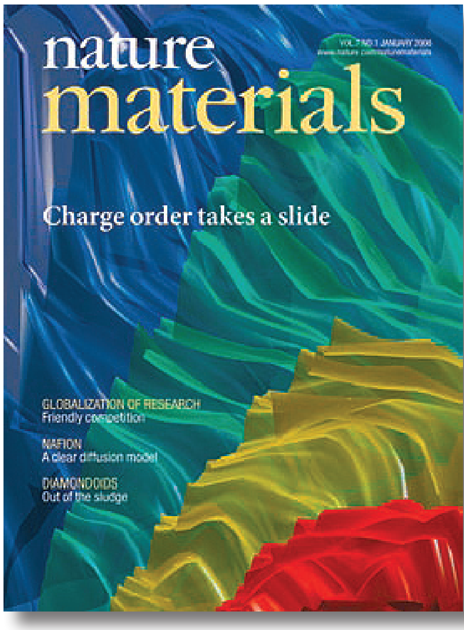
The *(surprisingly common)* atomic harpsichord: sliding charge density waves in manganites



"Sliding charge-density wave in manganites," by Susan Cox, J. Singleton, R. D. McDonald, A. Migliori, and P. B. Littlewood appears in *Nature Materials* 7, (2008).

The famous musician and conductor Sir Thomas Beecham once compared the sound made by a harpsichord to the dancing of skeletons on a corrugated iron roof. By listening to tiny electrical noises caused by a similar (but microscopic) mechanism, MPA-NHMFL scientist Susan Cox has been able to unravel a twenty-year-old mystery in a class of technological materials called manganites.

The phenomenon of magnetoresistance a change in electrical resistance in response to an applied magnetic field has received much recent press coverage following the award of the 2007 Nobel Prize in Physics to Albert Fert and Peter Grünberg. Fert and Grünberg were joint discoverers of giant magnetoresistance (GMR), an especially pronounced form of magnetoresistance in thin films of metals: thanks to this technology, it has been possible to miniaturize hard disks so radically in recent years. Sensitive GMR read-out heads are used to read data from the compact hard disks used in laptops and some music players.

The manganites compounds of oxygen and manganese with other metals have an even stronger response to magnetic fields, known as colossal magnetoresistance. This has led to the idea that manganites could be used in next-generation magnetic storage devices, producing even more compact MP3 players and other hardware. However,

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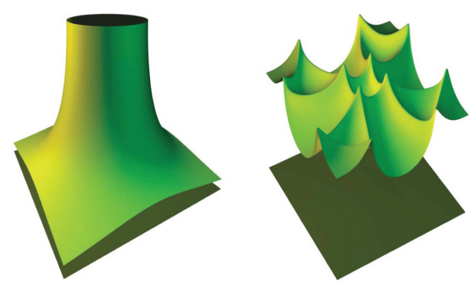
Superconductivity without phonons review in *Nature*

Researchers David Pines, MPA-DO, P. Monthoux, University of Edinburgh, UK, and G.C. Lonzarich, University of Cambridge, UK, have published a review in *Nature* of superconductivity without the mediating role of lattice vibrations (phonons).



Effect of crystal lattice on the magnetic properties.

Superconductivity, the dissipationless flow of electrical current, is a striking manifestation of a subtle form of quantum rigidity on the macroscopic scale. In real metals at low temperatures, but above the superconducting state, the experimental observations can be accounted for in terms of a low density gas of thermally excited particles with the same charge and spin, but not the same mass, as the electron. These particles are referred to as quasiparticles, which can be considered as an electron plus a co-moving screening cloud. In extreme cases, such as the heavy electron superconductors, the quasiparticles can behave as if they have greater effective mass than that of electrons and hence move relatively slowly. A full treatment of both the charge and spin degrees of freedom of the electron predicts the existence of attractive components of the effective interaction between electrons even in the absence of lattice vibrations. Such attraction without phonons can lead to electronic pairing and to unconventional forms of superconductivity that can be much more sensitive than traditional superconductivity to the precise details of the crystal structure and to the electronic and magnetic properties of a material.

Recent work at Los Alamos on $CeCoIn_5$ and related materials is particularly illustrative of these effects. The work appears in *Nature* **450**, (2007).

From Alex's desk

MPA: Building on our accomplishments for an exciting 2008

I hope you had a great break, are back ready and energized. We have an exciting year ahead of us—particularly because of the opportunity to apply our strong fundamental materials research expertise in collaborations with our current and future industrial partners. As I said in my first "From the Desk" note, MPA Division is indeed poised to solve real problems.

During the calendar year 2007, MPA published more than 300 peer-reviewed publications, delivered 100 invited talks in the United States and abroad, and was awarded three patents, while submitting an additional 29. MPA staff received around 16 achievement awards internally and externally to the Laboratory. Our industrial partnerships are also going strong. A partial list of current partners includes Nuvera Fuel Cells, 3M, Chevron Technology Ventures, Northeast Gas Association, United States Council for Automotive Research, General Motors, California Fuel Cell Partnership, Dana Corporation, Palmetto Fuel Cell Technologies, Smart Chemistry, Chrysler, Nissan Technology Center, Cabot Fuel Cells, Materials Modifications Inc., Northrop-Grumman, Mack Truck-Volvo, SuperPower, Inc., and Raytheon. Our technical staff continued to assist Oak Ridge National Laboratory's Center for Nanophase Materials Sciences, the Institute for Solid State Physics–Japan High Field Project, the Synchrotron Radiation Center, the Gordon Conference on Fuel Cells, and the FreedomCAR and Fuel Partnership's Code and Standards Technology Team, as well as several others by participating in activities involving external advisory and committees. We were also able to attract 17 new postdoctoral fellows during 2007. In addition, MPA's user facilities, the National High Magnetic Field Laboratory Pulsed Field Facility and the Center for Integrated Nanotechnologies, hosted more than 200 users. We have started 2008 really well. During this month alone the Division is involved in three energy-related working groups (one in Golden, Colorado and two more in Detroit) and CINT's user's meeting in Albuquerque was well attended.

Folks, this is really great, and congratulations to you all for the great job!

Let me also take this opportunity to wish best of luck to the MPA staff that chose to take the Laboratory's Self-Selection Program. Please join me in wishing the best in their new endeavors to Jeff Roberts, MPA-CINT, 25 years of service; Stephen Foltyn, MPA-STC, 26 years of service; Ken Stroh, MPA-11, 24 years of service; Judith Valerio, MPA-11, 22 years of service; Mahlon Wilson, MPA-11, 16 years of service; and Francisco Uribe, MPA-11, 17 years of service. As people are what make MPA so strong, we will indeed be sad to see you all go, but good luck! Cathy Padro, who joined Los Alamos in 2003 from the National Renewable Energy Laboratory, is the acting MPA-11 group leader. At Los Alamos Cathy has served as project leader for hydrogen and biomass systems, a member of the FreedomCAR codes and standards technology team, a Department of Energy liaison to global

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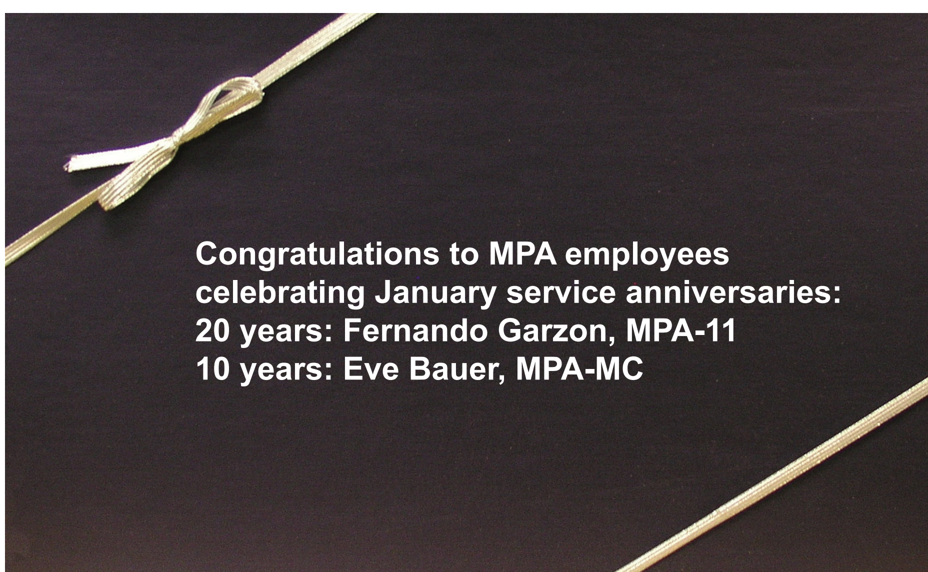


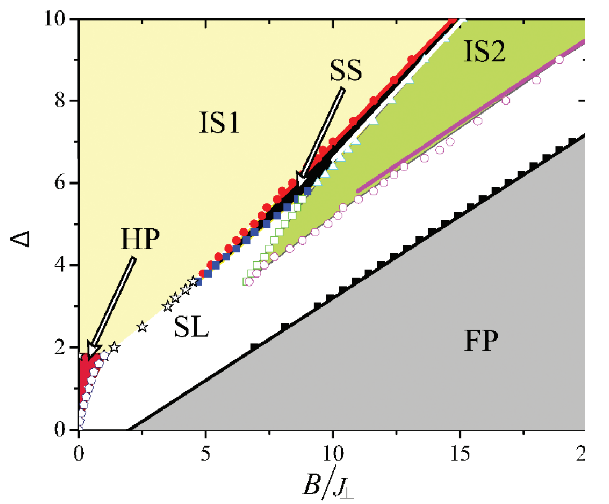
Spin supersolid in anisotropic spin-one Heisenberg chain

In the search for novel states of matter Los Alamos scientists have shown that a spin supersolid phase can be induced in a spin system by a uniform magnetic field under realistic conditions.

Using an exact analytic approach, MPA-NHMFL and T-11 postdoctoral researcher Pinaki Sengupta and Cristian Batista, T-11, demonstrate that the ground state of a S=1 Heisenberg chain with uniaxial exchange (Δ) and single-ion anisotropy (D) is a spin supersolid for a range of magnetic fields.

This is surprising, as one-dimensional solid phases are usually unstable towards solitonic excitations that destroy the solid order when the density deviates from commensurate values. Here, the solid phase stabilized by the exchange anisotropy and the solitons remain as massive excitations for a finite range of densities, thus stabilizing the supersolid state.

The research appears in *Phys. Rev. Lett.* **99**, (2007) and is supported by Laboratory-Directed Research and Development funding through the Center for Nonlinear Studies and National Science Foundation funding through MPA-NHMFL.



Quantum phase diagram in the Δ-B parameter space with D=Δ/2. SS denotes the spin supersolid phase. IS1 and IS2 are the gapped Ising phases while HP and SL denote the Haldane phase and spin liquid ground states.

"Desk" *Continued from page 1*

technical regulation activities for hydrogen and fuel cell vehicles, and as acting MPA deputy division leader following the 2006 transition. Please join me in welcoming Cathy to her leadership role.

In my January 11 e-mail I described the process and the Division's priorities for the LDRD-DR (Laboratory Directed Research and Development-directed research) call. MPA is seeking proposals that address the following strategic objectives:

1. Energy security: We are particularly interested in expanding our portfolio of activities in alternative energy technologies. We see future opportunities in energy storage technology as well as exploiting the MaRIE initiative in "Integrated Solid State Solutions for Energy." Our goal is to carve a unique niche in energy relevant science and technology for future program development. In addition, we see opportunities to support MaRIE initiatives in developing radiation-resistant materials for nuclear energy applications. Due to current DRs ending in 2008 there is a good opportunity to continue to support fundamental research on nuclear fuels, which could be of mutual interest to MPA and our sister divisions.

2. Superconductivity and actinide science: Beyond the interest in actinides as nuclear fuels we have a continuing interest in the fundamental physics and chemistry of actinide materials. We continue to have an interest in strong proposals in condensed matter physics addressing 4f and 5f systems.

3. Fundamental understanding of materials: We are particularly interested in concepts that will enhance the value of our national user facilities and position us to support MaRIE. Proposals that bring together Laboratory capabilities (e.g. NHMFL, CINT, and the Lujan Center) with strong, science-based collaborations are encouraged. In addition, proposals that develop new tools for advancing our understanding of materials across length and time scales or that support MaRIE are of interest.

4. Threat reduction: We are interested in ideas providing opportunities to develop programs relevant to the Laboratory's threat reduction mission.

To assist with the Division endorsement process, the MPA Council will host an LDRD–DR half-day discussion with potential principal investigators January 29. Our intent is to hear directly from the PIs and to help the best we can to make the proposal even stronger.

In summary, 2007 was great and I'm sure 2008 will be even better.

—Interim MPA Division Leader
Alex H. Lacerda

Heads UP, MPA!

Swagelok training available
Representatives of Swagelok from Albuquerque Valve and Fitting are offering a tube-fitting training course to Los Alamos employees upon request.

Last year members of MPA-MC participated in the course taught by Swagelok representatives Ron Burns and Jim Weybrecht of Albuquerque Valve and Fitting. Group leader Kevin Ott and Group Administrator Debbie Allison-Trujillo (665-4228) organized the training, which was offered at no cost to the group with content tailored its needs and research activities. The class included theory, proper installation techniques, common failure types, and matching the correct equipment with intended use. It also included a hands-on segment where participants assembled systems and had their work critiqued by the professionals, as well as a focus on troubleshooting the "seven deadly sins" of pipe/tube fitting. Examples of improper installation were presented and errors were identified by the participants. The training concluded with an informative question and answer session, leaving all participants with a sense of having learned something new, regardless of their experience level.

Allison-Trujillo worked with Burns and Phil Grogin of ESH-OFF to ensure participants received credit for low and high pressure safety and compression fitting training. The syllabus included 80 percent of material from the Laboratory's pressure safety course, but was also geared to the group members' specific activities, which helped them keep current with their training as the Laboratory courses are offered only every couple months and are limited to less than 20 people.

Groups may want to consider contacting vendors they regularly use to inquire if they offer specialized training.

Contacts: Debbie Allison-Trujillo, 665-4228; Ron Burns, (505) 842-0213

Nekimken elected chair of Institutional Worker Safety and Security Team for 2008
Howard Nekimken is the new chair of the Institutional Worker Safety and Security team, replacing Felicia Taw of Chemistry Division who served as the WSST chair in 2007. Nekimken, LANSCE-DO, has been at the Laboratory for more than 22 years, working in a wide range of areas and is involved in operations in the Experimental Physical Sciences Directorate (ADEPS) as well as at LANSCE. He has been an active member of the WSST since April 2007 and chaired the ADEPS WSST and co-chaired the LANSCE and Accelerator Operations & Technology WSST.

Your MPA contacts are:
Chris Sheehan (chair), MPA-STC, *sheehan@lanl.gov*
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Heads UP, MPA! reports on environment, safety, and health, security, and facility-related news and information.

Thermoelectric measurements of non-equilibrium dynamics in CDW materials

MPA-NHMFL's Ross McDonald recently presented his work on thermoelectric measurements of the non-equilibrium dynamics in charge density wave (CDW) materials at the recent seventh International Symposium on Crystalline Organic Metals in Peniscola, Spain. This work, performed in collaboration with Neil Harrison and John Singleton, also MPA-NHMFL, utilized large magnetic fields (B ~ 35 T) and low temperatures (T~50 mK) to measure the thermoelectric properties of the collective phase excitation of a CDW.

A CDW is an ordered ground state that forms in low dimensional metals due to the coupling between the electrons and the vibrations of the crystal lattice. As a result the phase excitations or phasons, which correspond to the density wave sliding, have strongly coupled charge and vibrational degrees of freedom. Phasons are thus expected to make large contributions to the materials thermoelectric properties, *i.e.* the coupling of current and heat flow. The difficulty in measuring this effect is that impurities and defects pin the CDW, preventing it from freely sliding.

In conventional transport experiments, the CDW may be depinned by the application of a relatively large electric field, resulting in highly non-ohmic behavior. However the application of a large electric field is incompatible with a thermoelectric measurement in which a small voltage is induced in the presence of a thermal gradient. This is especially true in CDW materials where the Fermi surface is only partly gapped, as the "normal" carriers give rise to a large current. In a high magnetic field however, these "normal" carriers

"CDW" continued on page 5

Volunteers sought for science and engineering night

Discover E is the sixth annual Engineers Week event sponsored by the Los Alamos Chapter of ASM, the materials information society, and the Northern New Mexico Chapter of ASME (American Society of Mechanical Engineers). This evening of interesting, interactive, and fun engineering, science, and technology demonstrations will be held February 20 from 4:30 to 7:30 p.m. in the Los Alamos High School DECA cafeteria.

Volunteers are needed to help organize and provide demonstrations and support for this event that attracts more than 250 kindergarten through high schools students and their parents/guardians from northern New Mexico. Setup time starts at 4 p.m. and clean-up is complete by 8 p.m. Contact Bev Aikin (bevaikin@lanl.gov, 667-1679) or Zana Konecni (konecni@lanl.gov, 665-5546) by January 30 if you are interested in helping.

Please send the title of your demonstration, whether you need electrical power, and the approximate amount of table or floor space needed. Volunteers are needed to help with registration and/or food service tables as well.

"Manganites" *Continued from page 1*

in spite of the resulting huge research effort, many of the electronic properties of the manganites have remained cloaked in mystery. A particular puzzle has been their electrically-insulating phase; for several years, this was assumed to be due to the mobile electrons (that would normally carry an electric current) becoming localized on particular atoms. The recent NHMFL research shows that this is not the case; instead, the electrons collectively form a wave-like entity, known as a charge-density wave (CDW).

If one could make a three-dimensional picture of the electrical charge in a CDW, it would look something like a sheet of corrugated iron spread throughout the manganite crystal. If the crystal were really pure, it would be possible for the CDW to slide around freely when an electric field were applied, just like the sheet of corrugated iron would do if it were dragged across a highly-polished smooth floor. Hence a current would flow and the crystal would be a conductor, not be an insulator. However, a real crystal contains impurities and defects to which the CDW becomes pinned; the effect is as though the corrugated sheet is now resting on a lumpy surface made (say) out of gravel. Now a large electric field has to be applied before the CDW moves and a current flows; the crystal is an insulator. In the same way, a large force would have to be applied to the corrugated iron sheet to drag it across the rough surface of the gravel. And dragging the sheet across the gravel would make a huge jangling, clattering noise, rather like Sir Thomas's skeleton-powered harpsichord simulation. The NHMFL researchers have identified the CDW by detecting the electrical equivalent ("noise") of the tiny clattering sounds it makes as it drags across the impurities in the crystal.

Not only does this discovery completely shake up existing preconceptions about manganites, it also suggests additional applications. In a recent MPA patent, CDWs have been proposed as the basis for completely new high-speed electronic devices involving nanotechnology.

Lead investigator Susan Cox said, "The observation of a charge-density wave in manganites opens up a new class of materials that may be used in such nanodevices, perhaps resulting in magnetoresistive nano-read-heads with integrated processing circuits."

Several technologically-important compounds of other metals and oxygen exhibit similar insulating behavior to the manganites, and it is possible that the CDW mechanism is much more common than previously thought. "They were wrong about manganites, and so my discovery means that ideas about a whole range of compounds might need to be rewritten" Cox concluded.

The research by Cox, John Singleton, Ross McDonald, Albert Migliori, all MPA-NHMFL, and P.B. Littlewood, University of Cambridge appears in *Nature Materials* **7**, (2008).

The work was funded by the Seaborg Institute and the Laboratory's Directed Research and Development Program. The sample was grown at the University of Cambridge where research was funded by UK EPSRC. Work at the NHMFL is performed under the auspices of the National Science Foundation, the State of Florida and the US Department of Energy.

"CDW" *Continued from page 4*

are orbitally quantized, which in combination with the CDW pinning can lead to significant departures from thermodynamic equilibrium. As the orbital quantization changes with magnetic field, the CDW is stretched and compressed causing it to de-pin. By measuring the current flow in response to a thermal perturbation that reduces this pinning the phason contribution to the thermopower could be measured.

Because CDWs occur in a wide range of systems ranging from organic molecular metals to elemental uranium, understanding their properties impacts a wide range of materials science.

This work was supported in part by the National Science Foundation, the Department of Energy, and the State of Florida.